SECTION II—GENERAL METEOROLOGY.

CLASSIFICATION OF THE HYDROMETEORS.[1]

By Dr. GUSTAV HELLMANN, Director.

[Königl. preuss. Meteorologische Institut, 1915.]

(Translated for the MONTHLY WEATHER REVIEW.—C. A. Jr.)

INTRODUCTION.

The present work endeavors to erect and establish a *complete* system of the hydrometeors [i. e., of the atmospheric phenomena which owe their origin to the presence of aqueous vapor in the atmosphere.]

It is remarkable that such an attempt has not been previously made, since the precipitations of atmospheric water vapor in the liquid and the solid forms have always formed an important chapter in meteorology. Aristotle and his successors discussed all those chief forms of condensation of aqueous vapor which occur in Greece or in the eastern Mediterranean—viz, Rain, Snow, Dew, Frost (Reif), and Hail. They did not discuss the clouds, which did not enter into scientific discussions until 2,000 years later. Yet as the teachings of Greek meteorology became known throughout central and northern Europe, the meteorological treatises are not found to add other hydrometeors to those just mentioned, although Glatteis [i. e., the ice coating called "glazed frost" by the English] and rime (Rauhreif) must have been often observed in impressive and disturbing forms.

Probably the reason for this omission—aside from the great authoritative influence still enjoyed by the Aristotelian system—lay in the fact that the students of those days wrote, almost without exception, in Latin and so had no expressions for hydrometeors not already mentioned in the writings of the ancients. In classic times as well as during the Middle Ages, interest in these matters was far too slight to evoke the invention of new words to name phenomena that, in any case, were rare. The phenomena probably were known, but one and the same word was applied to related processes. Thus "pruina" (Reif, frost) may also often mean rime (Rauhreif), which occurs not so rarely in northern Italy.[2] Similarly the word "grando" (hail) probably served also to designate our snow pellets (*Ger.* Graupeln, *Engl.* soft hail), just as to-day the English language makes no distinction between the two forms of the precipitate "hail."[3] We find hail and "graupel" first clearly differentiated and distinguished by Albertus Magnus, who drew attention to the differences during his residence in Cologne where "graupel" is of frequent occurrence as it is throughout Low Germany. In his paper "De passionibus aëris," written about 1270 A. D., after writing on hail, Albertus Magnus devotes three chapters to graupel "De granulis cadentibus in Martio vel Aprili." In subsequent years we sometimes find the encyclopædic articles of the fourteenth and fifteenth centuries as well as the textbooks of the sixteenth century, treating of these "granula congelata" in addition to the five hydrometeors discussed by Aristotle. Additional hydrometeors are not mentioned, but on the other hand several nonrelated phenomena, such as mildew (Mehltau), "manna," etc., are classed here.

Specific terms for even the rarer hydrometeors were developed much earlier in the languages of the common peoples, but these terms did not find places in published works because the latter were written almost exclusively in Latin until the middle of the sixteenth century in France and Italy, and until the end of that period in Germany.[4]

This is the reason why some of the hydrometeors not treated of by Aristotle receive no mention until quite late in history—really first in the meteorological textbooks of the second half of the eighteenth century—and why confusions of fact and of names occur. Indeed *we lack precise, definitions and a strict terminology.* A beginning along these lines was first made in 1873 by the Second International Meteorological Congress at Vienna, which introduced international symbols for abbreviating the entries of observed hydrometeors and other meteorological phenomena and also determined some of the concepts; to be sure the latter proved somewhat too brief in many cases. The results of this agreement were that the "Instructions to Observers" of the various countries were fitted to the new definitions and symbols, whereby again all kinds of errors crept in, either because (as was the case with the southern countries) many of the solid forms of condensation were but little known or because the respective languages contained no word for a phenomenon of rare occurrence in those countries. There has resulted an exchange of ideas throughout the last decennia, concerning the concepts of the hydrometeors, taken part in notably by Schönrock, Köppen, Pernter, Schiptschinsky, Johansson, A. Wegener, and (lately) Ciro Chistoni.[5]

---

[1] *Hellmann, G.* System der Hydrometeore. Berlin, 1915. 27 p. f°. (Veröffentl. d. k. preuss. Meteorol. Institut. Nr. 285.; Abhdlgn. Bd. 5, Nr. 2.)

[2] This is the sense in which is to be taken, e. g., Virgil's "circumfusa pruinis corpora magna boum."

Similarly in the oldest weather journal preserved to us, that of W. Merle at Driby near Oxford (1337–1344), "pruina" must often mean rime (Rauhreif) when it reads, as for December 8, 1340, "*pruina magna et nebula magna et gelu temperatum*"; because in a heavy fog it is rime, not frost, that forms.

The word "pruina" is still preserved in Italian, and Gerosa (Elementi di meteorologia. Livorno, 1909. 8°. p. 167) gives it the significance of rime.

[3] In Merle's journal there often occurs the entry "ventus magnus cum nive, pluvia et grandine multoties in die." The English translation accompanying the journal, speaks of "hail"; but it is evident that Merle here meant squally weather with frequent alternations of rain, snow, and graupel (snow pellets).

The English meteorologists have recently devised the special name "soft hail" to indicate graupel: but that name is not known to the general public and has not always found acceptance by the specialists. Thus Mossman, in his observer's journal from the Weddel Sea always writes "hail (graupel)," and others have used the term "snow-hail." An attempt to determine the distribution of these hydrometeors from the older English and American publications, best shows how disconcerting can become this use of "hail" for both hail and graupel. It is only when they are described in detail, as in the journal of the observer on Pike's Peak (4308 m.) in North America, that the specialist can judge whether "hail" means hail or graupel.

[4] In the weather journal kept by the prior Kilian Leib at Rebdorf/Nürnberg, from 1513 on (see Schottenlohner's contribution to Riezler-Festschrift, 1913), the journalist sometimes had recourse to German expressions, e. g., "pruina, quam vulgus 'duft' appelat." This expression, to-day common in southern Germany and Austria, dates back to the Middle Ages. In Heyne's Wörterbuch I find a citation from the Minnesingers (12th to 13th cent.) which shows that the people at that time distinguished between hoarfrost (Reif) and rime (Rauhreif) or Duft (tuft), viz,

"Swaere tage und scharfer luft
machent is, sné, rifen, tuft."

The French word "grésil" (Graupel) illustrates how slowly popular designations are adopted into the language of the students. According to Godefroy's "Dictionaire de l'ancien langue française" the word (grezil) occurs already in the Chant de Rolande of the 11th century. The oldest Meteorology in French (A. Mizauld "Le mirouer de l'air," Paris, 1548. 8°) adopts the term, but *hesitatingly*, for the caption reads "De la generation de Gresle, & dragetõs glacez: ou si voulez gresil." Further on in his text the "Graupeln" are described as "petitz rõdeletz dragetõs." The word "dragetons" I did not find in the French dictionary mentioned; it is probably derived from "dragée," which also signifies a mixture of small grains.

[5] *Schönrock*, Repertor. f. Meteorol., St. Petersburg, XI. Kl. Mit. Iii.

Köppen, Meteorol. Ztschr., 1887, 4:[70]; 1888, 5:[75].

Pernter & Schiptschinsky, Bericht über die meteorol. Direktorenkonferenz in Innsbruck 1905. p. 83 ffg.

Johansson, Meteorol. Ztschr., 1905, 22:28.

Wegener, in his "Thermodynamik der Atmosphäre."

Chistoni, is now stationed at Naples to be sure; but his former long residence in northern Italy made him acquainted with many hydrometeors that are rarer in the south. He has published the following 5 contributions in the Rendiconti d. r. accad. d. sci. fis. e matemat. d. Napoli, 1910 and 1911: "Ruggiada e guazza," "Brina, galaverna e calabrosa," "Gelicidio," "Sulla formazione della brina," "Sopra una notizia del Dott. W. Knoche riguardante la formazione del Glatteis."

I had to consider this question in some detail while editing the International Meteorological Codex, and I found that heretofore some forms of aqueous condensation have not been considered at all and that even the most comprehensive meteorological texts are deficient in this respect. I therefore resolved that sometime I would endeavor to draw up an exhaustively complete system of the hydrometeors. The present communication has that for its object.

Of course we here have to endeavor to determine the mutual limits of the individual forms of precipitation of atmospheric water vapor—in so far as Nature herself knows any such sharp delimitations, for these formations also have transitional forms—rather than to develop the still very incomplete theory of the phenomena. Nevertheless, the genetic point of view will be held to as far as possible, because only in this way can one secure a fixed concept in some cases. The discussion will be very brief, for such well-known hydrometeors as rain, dew, hail, which are not likely to be confused with others, and I shall treat in detail only the newly proposed forms and some that are less sharply defined. In the latter cases it will sometimes be advisable to add something about the temporal and areal distribution of the phenomena. The nomenclature will also be considered.

The following schematic summary contains those forms of condensation of atmospheric water vapor which represent independent phenomena. They are arranged in the three natural groups: (1) Direct condensations at or close to the earth's surface; (2) direct condensations in the free air (the clouds); (3) indirect condensations in the free air (precipitates falling from clouds). Under each group the corresponding forms of fluid and solid aggregates are set in parallel columns.

Finally, before passing to the discussion of the individual hydrometeors, I would say that we shall here concern ourselves with only the hydrometeors in the narrow sense of the word—viz, those forms of condensation that bring directly to the earth water in its liquid or solid form—so that the clouds (forming a chapter by themselves) are not considered at all.

SYSTEM OF HYDROMETEORS.

(1) Direct condensations of water vapor at or near the earth's surface.

Liquid.		*Solid.*	
"Sweat"	(Beschlag).		(Frostbeschlag).
Dew	(Tau).	Frost, hoarfrost	(Reif).
Mist waters	(Nebelwasser). (Nebeltau).	Mist ice	(Nebeleis).
		Ice fog	(Eisnebel).
Wet fog; "Scotch mist."	(Nebelreissen).	Rime	(Rauhreif). (Rauheis).
Fog drip	(Nebeltraufe).		
Rain without clouds.	(Regen ohne Wolken).	Snow without clouds.	(Schnee ohne Wolken).

(2) Direct condensation of water vapor in the free air.

Liquid.		*Solid.*	
Water clouds	(Wasserwolken).	Ice clouds	(Eiswolken).

(3) Indirect condensation of water vapor in the free air.

Liquid.		*Solid.*	
Rain	(Regen).	Snow	(Schnee).
		Graupel	(Graupeln).
		Hail	(Hagel).
		Sleet	(Eiskörner).
		Glaze or glazed frost	(Glatteis).

(1) DIRECT CONDENSATION OF WATER VAPOR AT THE SURFACE.

Sweating, Sweat (Beschlag; Wässriger Beschlag).

The watery coating here referred to is of two kinds. *A*. During the afternoons of warm, clear Fall days, when the atmospheric content of water vapor is still rather high—in Berlin it amounts on the average to 7.1 mm. in October as compared with 5.7 mm. in April and 4.8 mm. in March—the street pavements that lie wholly in the shade, as on the north sides of houses, become coated with a thin film of water. This moisture does not gather into drops, but one can clearly perceive that the paving on the shady side of the street, is darkened by the moisture and stands out in contrast with the dry and therefore brighter paving across the way. Streets running north–south into which the sun shines, and large open squares, do not show this moisture, while in an east-west street it may persist on the shady side day and night.

Of course this deposit is not the unevaporated remains of a previous rain but is a precipitation of the water vapor of the lowest air layers whose temperature has been brought below the local dewpoint by reason of the constant day and night radiation of the underlying stone surface. The process is, therefore, similar to the formation of dew (Tau) which also not rarely begins before sunset. If, nevertheless, I do not class this phenomenon with dew (Tau) it is because in the latter case both soil and air furnish the moisture for condensation, while the air alone supplies the moisture condensed as sweat (Beschlag), (1). The soil moisture can not rise through thick stones or asphalt paving.

B. In the colder half of the year when a warm and very moist air current sets in suddenly after a rather long but only moderately severe cold period, stone walls, marble and granite house facings, etc., develop a moist coating. In popular language "The stones sweat" (Die Steine schwitzen). The stone has not been able to keep pace with the rapid change in temperature of the outside air, the moist air coming in contact with the stone is cooled below the dewpoint and compelled to give up some of its moisture.

In this kind of "sweating", which in contrast to that discussed under *A* affects vertical walls, the accompanying weather is generally cloudy. The "sweating" does not continue for long, but is more copious than the variety first mentioned. (2).

Frostbeschlag.[6]

When such a sudden change of weather as has just been described, occurs after a long period of severe cold then the house walls, stones, etc., are so chilled that the dew point of the warm moist air directly in contact with them is depressed below 0°C., and a solid deposit similar in appearance to frost forms on them. This deposit is also well seen on smooth-barked tree trunks such as the beech. In popular language "the cold is coming out" (Die Kälte schlägt aus).

[6] The author is unable to decide whether there occurs an ice coating (Eisbeschlag) corresponding to the first kind of sweating (Wässriger Beschlag, *A*). and resulting from the freezing of the latter; he himself has never observed such a phenomenon. Such a transformation would, however, probably be possible at elevated points in the mountains where the temperature often rapidly falls to below 0°C. after fine clear days in the Fall.

Here reference may be made to an ice formation repeatedly observed by Ratzel, but of which he could find no published description (Das Wetter, 1889. p. 216). Perhaps here also belongs an ice formation observed by Knoche in Chile and by him classed—I think incorrectly—as Glatteis (Meteorol. Ztschr., 1911, 28:93).

By means of a magnifying glass one can see that the ice film thus formed is made up of crystalline columns standing close together perpendicular to the surface and uniformly 1 or 2 mm. high, somewhat like hoarfrost (Reif) that forms on a bench during a clear night. One can write and draw patterns in the deposit. Amorphous forms also occur, however, particularly when the film is very thin can one see closely crowded ice points.

This frost coating (Frostbeschlag) endures relatively a long time when in the shade, and may last as long as 1½ days if the preceding cold was very severe.

In some of the older textbooks, and even in the more recent ones, "Frostbeschlag," if mentioned at all, is falsely described as rime (Rauhreif). As will be shown below, rime is altogether different in nature and origin.

Dew (Tau).

Dew is so well known, by reason of its widespread occurrence, and is a hydrometeor of such definite form that there is scarcely any difference of opinion as to its definition. Christoni draws attention to an observation by Fusinieri [7] that even under the trees a certain amount of dewiness is sometimes present on the grass when the sky is cloudy. This kind of light dew will usually escape the attention of the ordinary observer, who, indeed, will note the dew drops hanging on grass-blades and leaves, but does not examine the grass more closely for moisture.

We distinguish between evening dew and morning dew according to the time of day when it is observed. The morning dew, which has formed during the long night, is naturally more frequent and more copious than the former. The Romance languages have a separate word for evening dew or evening moisture, viz, serein (*Fr.*), sereno (*Ital., Span., Port.*).[8]

Hoarfrost, Frost. (Reif).

"Frost is frozen dew," so runs the stereotyped explanation of most textbooks and instructions. It is a very ancient statement, obviously dating back into antiquity, perhaps coming from Chrysippos or from Pliny (Hist. Nat. 61) or from the pseudo-Aristotelian work *περὶ κόσμου*; while Aristotle himself explicitly says that when frost is formed the water vapor solidifies directly.

The Stoic Chrysippos lived in the third century, B. C., and according to the statements of Stobaios, taught that *πάχνην δὲ δρόσον πεπηγυῖαν* (cf. Diels, Doxographi Graeci, p. 468, 5).

In the work *περὶ κόσμου*, which Zeller (Philos. d. Griechen, IIIa, p. 645) thinks probably dates from the first century before or after Christ, there occurs a remarkable passage referring to frost which, I think, has not been properly interpreted. After having again remarked of frost *πάχνη δὲ δρόσος πεπηγυῖα*, it goes on to say: *δροσοπάχνη δὲ, ἡμιπαγὴς δρόσος*. So that "dew-frost" is a half frozen dew. Barthélemy Saint-Hilaire (Météorologie d'Aristote. Paris, 1883, p. 374) translates the word *δροσοπάχνη*, which seems not to occur again in Greek literature, somewhat boldly by the word rime (Rauhreif), which is actually incorrect. This translation is also in contradiction to the translator's assumption that Apuleius of Madaura is the author of the manuscript; for how should an author from Africa come to mention rime when, from his own experience, he could scarce know what frost is?

The old idea that hoarfrost is frozen dew, to which idea Chistoni distinctly adheres, is not correct in this general sense. It is true that often enough it happens that dew first forms and that, if the temperature continues to fall, the dew passes into the solid form. However, when in wintertime the dewpoint is initially below 0° C. the water vapor must pass directly into hoarfrost. Were hoarfrost always frozen dew, then one should frequently find the individual dewdrops which lie in the leaves to have been converted into ice balls. The writer can recall but few occasions, and those were in the Fall, when he observed such a phenomenon.[9]

If the dewpoint lies close to 0°C. it may happen that, according to the radiative power of the object, dew and hoarfrost may form side by side.[10] In this case the hoarfrost is usually more copious because the vapor pressure over ice is lower than it is over water, and therefore the water vapor condenses more readily upon the frost.

Chistoni further claims that frost formation does not extend beyond a level of 2 meters above the ground and that the frost-like phenomena observed at greater heights is rime (Rauhreif). This, however, is altogether contradictory to experience in our northern countries.[11] Here frost forms both on the ground and on high roofs over 25 meters in height, while at the same time the twigs and branches of equally lofty trees remain quite free of it. This would not be the case were the formation rime (Rauhreif). The formation of hoarfrost requires intense radiation outward toward the sky, and as this can proceed unhindered from a roof it appears quite natural that hoarfrost forms on more or less horizontal surfaces at greater heights above the ground when there is sufficient water vapor present. Rime on the other hand, is precipitated from the elements of fog blowing past terrestrial objects and therefore its delicate forms coat objects having an upright position.

Hoarfrost does not always possess a crystalline structure even though its macroscopic appearance suggests it, and Assmann showed this in 1885. Since that time Prinz, Grossmann, Lomas, [and Bentley],[12] have revealed to us such a quantity of crystalline forms of hoarfrost (Reif) that I am inclined to regard its amorphous form as the exception. This subject requires, however, further and more long-continued investigations.

The most beautiful frost figures I have seen—on only one occassion, to be sure—had formed in a sheltered spot and under moderate cold (minimum was −5°C., 23°F.). They were small hollow six-sided pyramids standing on their points with the opening turned upwards like a funnel. [See also Bentley's photographs, loc. cit. Plate V, fig. 37; Plate XIV, fig. 116; Plate XXV, fig. 225.—*C. A. jr.*] Grossmann & Lomas were able to study these forms more intensively during Christmas, 1892, in northern England, and they showed at that time the complete similarity to the funnel crystals which form in ice caves [13] where they are able to develop with special regularity and to a great

[7] During the 30's and 40's of last century the Italian investigators Fusinieri, Zantedeschi, Melloni, and Bellani carried on a lively discussion concerning the laws of radiation and the theory of dew formation, whereby some new details were brought to light. Quite recently Sutton of Kimberly has made some interesting communications concerning the formation of dew under a cloudy sky (Meteorol. Ztschr., 1915, 32:32).

[8] See the remarks below, under "Rain without clouds" for a false significance of the French "serein."

The use of "sereno" in Italian is found in Paci's "Saggio di meteorologia" (Napoli, 1834. 8°, p. 436). I cite this authority expressly because the great Italian dictionaries of Petrocchi, Rigutini, and others, do not give this meaning for "sereno." A somewhat different significanace—viz. mist over the meadows in the evening—is found in A. Bellani's "Della rugiada, della brina, . . . " (1831). In Spanish "sereno" means in general the moisture of the evening or the night (Diccionario de la Lengua Castellana por la Academia Española), and likewise in Portuguese.

[9] It is reliably reported that this frozen state of originally liquid dewdrops has been frequently observed during August in the Rocky Mountains at altitudes of 6,000 or 7,000 feet above sea level.

Cox mentions it but once, apparently, in his monograph on frost conditions in Wisconsin cranberry marshes and regards it as a "peculiar phenomenon." (Weather Bureau bulletin T, Washington, 1910. p. 89).—C. A. jr.

[10] Perhaps the above-mentioned "dew frost" (*δροσοπάχνη*) refers to this phenomenon.

[11] At the observatory of Potsdam (Berlin) there are, on the average, 60 days with hoarfrost (Reif) per year, while at Palermo (according to Chistoni) there are but five such days. It would appear from this that observers in northern Europe have much more frequent opportunity to observe hoarfrost than do those of southern Italy.

[12] Assmann *in* Meteorol. Ztschr., 1885, 2:46–7.

Bentley *in* Monthly Weather Review, Nov., Dec., & Ann. Sum., 1907, 35.

Grossmann & Lomas *in* Proc., Royal soc., 1894, 55; details in Nature, London, Oct. 18, 1894, p. 600.

Prinz *in* Ciel et terre, 1895.

Compare also the contribution by E. Budde on "Eiskrystalle" in Poggendorff's Annallen, 150: 577.

[13] *Schlagintweit.* Neue Untersuchungen über d. phys. geogr. d. Alpen. p. 469.

size by reason of the prevailingly quiet air. They are even found occurring in the cooling rooms of breweries. The frost figures, so-called "ice flowers," that form on the surfaces of glaciers often show beautiful forms.

Finally, I would refer to a remarkable ice growth in the soil, which must not be confused with frost. In the late fall or early winter, when the upper layer of soil is quite moist, one may at times see in the early morning, after a frosty night, little columns and tubes of ice literally growing up out of the slightly frozen ground and pushing the surrounding soil into little domes and rolls. These are the ice columns or ice filaments (Eisfilamente).[14]

Mist water, Wetting fog. (*Nebelwasser; Nässender Nebel*).

Water separates from a wetting fog (nässender Nebel) in two ways:

A. (*Nebeltau*).—On clear calm evenings in summer and fall, less frequently in the spring, about sunset or perhaps a little before, a light radiation or ground fog (Bodennebel, Strahlungsnebel) forms over moist meadows often to a height of but one-half meter. In the course of the night the fog may increase to a depth of a man's height or more. Its white color makes the fog visible at considerable distances and throws it into such contrast with the dark surroundings that one can trace its expanse long after sunset. Often meadows of many hectares extent are uniformly covered by the fog, more frequently, however, there are fog-free spots here and there which are usually somewhat higher and drier. If the sky remains clear through the night the fog grows denser with the markedly falling temperature and water separates out; the meadow becomes moist. (3)

Chistoni properly points out that this condensation may not be classed with dew. If the observer finds the fog still present at the morning observation he can readily differentiate between the fog moisture and the dew moisture, but if the fog has already disappeared then it is more difficult to distinguish them. I think, however, that my own observations justify the statement that the dew is readily known by its well-formed droplets while the fog moistens the leaves and grasses more uniformly.

In tropical localities where the water-content of the air is specifically high, dense ground fog (Bodennebel) forms precisely during the dry season and refreshes the plant world with a generous morning moisture. The "cacimbo" of Portuguese West Africa is a famous example of this phenomenon.

B. Wet fog (*Nebelreissen*).—Often the ground is covered by a fog denser than the meadow fog (Wiesennebel) which has just been described, and then it is a matter of indifference how the fog originated. As long as the mist droplets are very small their surface tension is so great that when they strike an object they rebound without bursting (dry fog). When the fog particles become larger, however, contact causes them to split up or burst into the finest droplets (wet fog, nässender Nebel). One says the fog "is bursting" (der Nebel "reisst").

The amount of water that separates out or is precipitated in consequence of the fog "bursting" is, of course, slight, and it becomes considerable only if the process continues for some time. Such is notably the case when brisk air currents drive large masses of "wet fog" (nässenden Nebels) against projecting objects; that is, when "wet fog" and driving fog (Nebeltreiben) occur simultaneously. In the free air the fog particles can strike only against one another, so that but few droplets result from the breaking up, but in forests there develops an actual rain under the trees. Leaves, bushes, and twigs catch the fog droplets, which run together into larger drops and then fall to the ground, so that the forest soil becomes thoroughly wet while the soil outside the woods is but moistened. This capture of water by the forests, which I would call "fog drip" (Nebeltraufe), is of great importance in forest economy and often has been wholly overlooked in studies on the influence of forests on precipitation. If these studies consist essentially of a comparison between the precipitation measured outside the forest and that measured in a clearing within the forest, then the process just described is altogether disregarded.[15]

Naturally fog drip yields the greatest amount of water on the lee side of a forest, so that mountain forests on the "weather side" or on the summits of mountain ranges occupy the more favored positions in this respect. A classic example of this feature is furnished by Marloth's measurements[16] on Table Mountain near Cape Town, where the vegetation captures much water from the driving clouds of the Southeast Trades during the dry summer season. The higher part of the dry island of Ascension also secures moisture in this manner.[17] In the lowlands of dry regions it is also frequently the case that wet fogs are the only source of the little water received by the vegetation. Typical examples of this are the "garúas" on the coasts of Chili and Peru, driving landward from the sea in the Winter and Spring they moisten the soil; similarly the frequent fogs along the coast of German Southwest Africa (Swakopmund has 149 days with fog per annum) have produced a fog-fed vegetation (Nebelvegetation) of their own.[18]

Mist ice (*Nebeleis*).

Ice separates out from fog either directly by sublimation or indirectly from subcooled fog droplets.

A. Ice-fog; frost-smoke (*Eisnebel*).—True radiation fog corresponding to the meadow fog or mist (Wiesennebel) of Summer, can not form in Winter when it is cold; but a fog due to mixture (Mischungsnebel) can form over warm spots. Many bodies of water (e. g., the Norwegian fjords, and particularly ice-free spots in the polar seas) form such warm spots. The water vapor rising from the water is at once sublimed in the cold air and the resulting ice particles, which may even be beautifully formed snow crystals, slowly sink to the earth. This ice-fog or frost-smoke[19] (Eisnebel, Frostnebel, Frostrauch, = *Norw.* Froströg) was first described, I believe, by the Hamburg whaling master Friedrich Martens[20] and later more accu-

[14] Readers of the REVIEW will find this phenomenon, which is not a hydrometeor in the strict sense, described, illustrated, and discussed in the MONTHLY WEATHER REVIEW, 1898, 26:217 (bibliography); 1905, April, 33:157-8, and Dec., 33:527 (illustr.). A detailed study of the related phenomenon of ice fringes on plants will be found in the August, 1914, issue, 42:490-499.—C. A., jr.

[15] It may not be out of place to here state again that the problem which has recently attracted renewed attention in the United States and in the Weather Bureau, is a purely meteorological one. It does not deal with forest economy and is: "Can the existence of forests induce or further rainfall, properly so called?" The answer must be based upon comparisons of measurements wholly free from such unrelated and disturbing phenomena as fog drip.—C. A. jr.

[16] Meteorol. Ztschr., December, 1906, 23: 547-553.

[17] See MONTHLY WEATHER REVIEW, October, 1898, 26: 466.—C. A. jr.

[18] Much fog is nothing else than low-lying cloud, therefore many might prefer to class wet fog (Nebelreissen) and its intensified form, "fog drip," with precipitation falling from the clouds. Transition stages of course exist. I have not so classed these two forms because certain fogs form only at the earth's surface and because a mountain dweller does not much care whether the mist (Nebel) that inwraps him is fog or cloud (Nebel als solchen oder als Wolke).

[19] "Frost smoke" is given by the Century Dictionary as the name of the fog of ice needles that forms over bodies of water during severe cold.—C. A. jr.

[20] *Martens, Friederich.* Spitzbergische oder Grönlandische Reise-Beschreibung, gethan im Jahre 1671. Hamburg, 1675. 4°. p. 39.

rately by W. Scoresby[21] who pointed out at the same time that when the wind drives "frost-rime" or "frost-smoke" against the ship the "frost-rime" deposits rime (Rauhreif) on the ship.

B. *Rime (Rauhreif, Rauheis).*—Rime (Rauhreif) is the rough (rauhe) frost-like deposit of delicate structure, which may be deposited at all hours during foggy weather at moderate to severe cold temperatures, on the branches and leaves of trees, on all corners, joints, and edges of upright objects. It forms not at all, or in insignificant amounts, on horizontal surfaces. Since it is built of the fog particles driven by the wind, it grows most rapidly on the windward side of objects, i. e., it grows against the wind. Rime does not form uniformly on all objects at the same height: the smallest twigs may be so loaded with it that they seem to be incrusted, while at the same time the branches and stem of the plant remain free from it. Thus a bush white with rime may stand out in striking contrast to the dark stem of a neighboring tree. If the tree trunk presents angular, pointed projections, however, such as would arise from previous damage to the bark, then rime forms on these projections. The leaves of evergreens and needle-leaved trees have rime form principally along their edges; similarly the edges of quadrangular posts, boards, etc., are more heavily coated with rime than are the surfaces between.[22] It therefore seems that those portions of the object which cool most rapidly and intensely, are the most favorable portions for the deposition of rime. Again, rime forms more plentifully at high levels because there the air movement is faster so that the supply of fog particles (Nebelelementen) is greater than at low elevations.

Rime has crystalline structure when sublimation occurs; it is amorphous when undercooled fog droplets solidify to ice upon striking the supporting object. The first manner of formation gives delicate, feathery forms which are readily recognizable as belonging to the Hexagonal System [of crystals]; the second method, which was first brought to public attention by Assmann on the Brocken in 1889, yields more compact ice deposits which are really Rauheis. Later Dobrowolski[23] made detailed studies of the structure of rime (Rauhreif) during the Belgian antarctic expedition and published numerous drawings of the forms it assumes. He found many more crystalline forms than amorphous ones; and even these latter, which arise from a succession of solidified droplets, seem to obey the laws of the Hexagonal System to a certain degree. This probably signifies that the sublimation of the water vapor, taking place alternately or simultaneously with the other process, induces somewhat of an hexagonal-system character in the whole pattern. As Assmann had already pointed out, the amorphous variety of rime gives the impression, to the naked eye, of being ice crystals. The usual meteorological observer would be unlikely, therefore, to accurately report the structure of the rime he observes; so that however theoretically correct may be Pernter's proposition to distinguish between the crystalline and the amorphous forms, it would not be possible to put it into practice.

Pernter proposes the name "Rauhreif" for the first or crystalline form and "Rauhfrost" for the second or amorphous form of rime. Since these two terms have heretofore generally been regarded as synonymous, the writer would prefer the name "Rauheis" for the amorphous variety. This name at the same time shows the relation it bears to the ice coating known in England as "glazed frost" (*Ger.* Glatteis, *Amer.* glaze).[24] In fact there must be a close relationship between the two deposits, for if Rauheis is formed from undercooled fog droplets while glaze (Glatteis), as will be shown later, results from undercooled raindrops, then the mode of origin of both coatings is essentially the same, although in the case of glaze (Glatteis) the drops of undercooled water spread out over horizontal surfaces at the same time they are solidifying into ice. If Rauheis and glaze (Glatteis) nevertheless do not present the same appearance, Rauheis giving rather a crystalline effect, then this must be due—as remarked before—to the circumstance that two processes are at work simultaneously in the latter case—the freezing of undercooled fog particles and the sublimation of water vapor. According as the one process or the other predominates the structure seems to be more amorphous or more crystalline; and it is conceivable that the frozen droplets may so predominate over the sublimate that the resulting Rauheis is scarcely to be distinguished from glaze (Glatteis).

Rime (Rauhreif) belongs largely to the lowland phenomena, Rauheis rather to the high mountain localities; because the winter fog of the lowlands rarely has undercooled droplets, while these latter frequently occur in the clouds which enwrap the mountain summits where they appear as fog (4). Of course rime deposits are not lacking on the mountains; under very low temperatures they are the sole form that occurs.

Pernter's statement, "Rime (Rauhreif) forms in calm, foggy weather during quite low temperatures, when great quantities of ice crystals are deposited from the ice fog (Eisnebel), upon objects (trees, bushes, etc.) . . . ," is in need of some correction. *First*, to the writer it seems superfluous to require that the ice crystals shall form in considerable amounts. There are all possible gradations in the development of the rime (Rauhreifbildung) from the most delicate ice feather barely visible to the naked eye, up to the mighty ice banners (Eisfahnen). *Second*, calm weather is not necessary for the formation of rime. If a calm prevails then, other things remaining the same, the deposit of rime will be insignificant. It is precisely in windy weather (during driving fog or Nebeltreiben) that rime forms in larger quantities, because then more fog particles (Nebelelemente) are driven against terrestrial objects. *Third*, "quite low temperatures" also are not a requisite. The observations at Potsdam from 1893 to 1913 teach that rime frequently formed at air temperatures of $-1°$ to $-2°$C., although the deposit was then slight. Heavy deposits of rime, on the other hand, occur under greater cold. *Finally*, the Potsdam observations make it questionable whether foggy weather always is present when rime forms. Thus, of the 144 days with rime recorded during the 21 years, there were some days on which no fog (Nebel) occurred; a clear sky (heiterer Himmel) or low degree of cloudiness prevailed, but on each occasion it was very cold ($-10°$ to $-20°$C.). If there was no confusion with hoarfrost (Reif)—and this can scarcely be determined subsequently, but appears improbable in some cases—we must conclude that such a sublimation may take place without antecedent condensation of the water vapor into fog (Nebel). Since actual fog (Nebel)

[21] *Scoresby, William.* An account of the arctic regions. Edinburgh. 1820. 2 v. 8°. vol. 1, p. 434.
[22] *P. Wilson* had observed this fact as early as 1780 in Glasgow. See "An account of a most extraordinary degree of cold," Phil. trans., 1780, 70: 451–473; [abr. ed., 1809, 14: 704–11.]
[23] *Assmann,* in Meteorol. Ztschr., 1889, 6: 339.
Dobrowolski. La neige et le givre. Anvers, 1903. 4°. (Résultats du voyage de S. Y. *Belgica* en 1897–1899.)

[24] Glaze (Glatteis) is a recently adopted American technical name preferred by the U. S. Weather Bureau over the English term "glazed frost." See this REVIEW, May, 1916, 44:285–6.

simultaneously prevailed in 96 per cent of all cases, I also have accepted its presence as a prerequisite (Bedingung) and included it in the above statement of the concept of rime (Rauhreif). The fog is indeed often very insignificant, being thin and shallow (nicht hoch), so that the blue sky shows through. Often the fog is nothing but a delicate haze (Duft). This word "Duft" probably meant originally the slight haziness of the air from which the rime deposited and later was transferred to the product itself (cf. footnote 4, p. 385).[25]

The following results, compiled from the Potsdam observations, will serve to illustrate the occurrences of rime in lowlands. The mean annual number of days with rime at Potsdam is 6.8; in 1895 there were 20 such days, in 1912 only 1 day. Distributed among the months the means are: January, 2; February, 1.3; March, 0.6; April, 0.05 (once in 21 years); November, 0.6; December, 2.2. The maximum in any month was 8 days. It is not rare to find rime forming on several days in succession; the extreme case was a series of 6 days (Dec. 9 to 14, 1894). This occurred in the winter having the largest recorded number of days with rime: From December, 1894, to March, 1895, there were 24 days with rime, of which 14 days came in December and January. In Potsdam the majority of cases show but slight or moderate amounts of rime; only nine times were there very heavy deposits, and of these occurrences December and January each had 4 and February had 1. On five of these occasions of heavy rime it was very cold (−16° to −24°C.); on another date the temperature fell but to −3°C., but on this occasion there was a heavy fog (starker Nebel) and the hygrometer stood continuously at 100 per cent, which is not the rule. Many days when rime forms, show relative humidites of 90 per cent or even lower.

Rime (Rauhreif) and Rauheis form most frequently and most heavily in the polar regions and on isolated mountain peaks which lie in the average level of the winter clouds and are not far from the sea or from the paths of LOWS. Ben Nevis, Scotland,[26] has a certain amount of fame in this respect, as also have the Brocken (Harz), the Schneekoppe (Riesengebirge), and the Bielašnica (Bosnia).

Rauheis starts to form on objects in a manner similar to that of rime, showing a preference for all corners and edges. If the process continues days, or even weeks, then the intervening surfaces also receive a deposit of ice (Eisansatz), and soon all upright walls are uniformly covered and appear to be wholly incrusted. By reason of its loosely knit joints Rauheis, like rime, readily breaks off under the action of stronger winds, and it also melts away rapidly in the sunshine.

The writer first made the acquaintance of the grotesque forms which the coating of rime [27] gives to objects, while visiting the meteorological observatory on the Schneekoppe in January, 1881. Impressed by the heavy ice coatings which convert, e. g., a telegraph pole into a heavy plank 50 to 70 centimeters wide, I formed the opinion that in addition to the amounts of precipitation caught in the rain- and the snowgages, the quantity of rime ought to be measured and added thereto. At my suggestion the observer there made such measurements and as follows: Every morning he scraped off the rime and ice which had formed on the 36-centimeter-high, cylindrical jacket of the gage, melted it and determined its water equivalent (Schmelzwassermenge). On reducing these equivalents to the area of the gage aperture so that they may be compared with the true precipitation, there result the following figures for 1881:

Month.	Reduced water-equivalent of rime.	Rain and snow.
	Mm.	*Mm.*
January 7–31	18.3	33.9
February	19.6	64.8
March	24.4	98.9
April	9.6	3.6
May	5.0	101.9
November	1.2	40.3
December	6.3	35.1
Total	84.4	406.5

The total amount of rime thus determined, accordingly amounts to 21 per cent of the other precipitation measured in the same months. (5)

Subsequent winter visits to mountain stations soon convinced me, however, that such measurements of rime have but a relative value and that even were it possible to determine absolute values the latter should not be added to the other precipitation. The grounds for this conclusion are as follows: By reason of the matutinal scraping off of the rime [and ice] the formation of new rime is furthered and more of the icy deposit is collected than would have been the case had the deposit been left undisturbed until it fell of itself from time to time. Furthermore, the wind direction is of considerable importance here. If the wind is from such a direction that the raingage stands in the lee of buildings, which would not affect the measurement of falling precipitation but would partially or completely screen the gage from the horizontal currents which bring the fog particles, then the deposit is much slighter than when the gage stands on the weather side. The principal reason, however, is that the heavy rime deposits on the mountain peaks of the Brocken, the Schneekoppe, etc., form only on upright objects, i. e., on objects set up by man. The larger the number of such objects the greater the quantity of ice taken from the clouds.[28] If they did not exist at all while the summit retained its natural character, then the slight natural inequalities of the surface would soon be smoothed out by the winter snow and the deposit of rime on the snowy gently inclined surface would be extremely slight. To be sure rime is deposited on snow, indeed it there often assumes a beautiful, large-leafed form, but such deposits are infinitely small compared with those on houses, telegraph poles and other objects that project freely out into the air. It is only when a mountain peak has steep rock groups that the formation of rime (and ice rime) would be favored in a natural way.

It seems to me that this consideration has a rather broad bearing. It is precisely the heavy rime deposits on mountain summits that have led to the frequently expressed opinion that in the polar regions of deficient precipitation the snow is chiefly supplemented by hoar-

[25] The term "Duftanhang" was also used, however. In Grimm's Deutsch. Wörterbuch, v. 2, 1500, I find the following old passage cited:
"daher man den tuft nebel nennet, die den luft und nebel im winter an die bäume blasen" [that is the reason why we call the frosting (tuft) by the name of fog (nebel) which the air and fog blow upon the trees in winter].

[26] The Ben Nevis meteorologists have called rime (Rauhreif) by the name "fog crystals." The occurrence of "brown fog crystals" there is most remarkable and they have not explained it; often, indeed, the observer's journal records "dark-brown fog crystals," while the next day perhaps "white fog crystals" is entered. Is this discoloration due to some dust and smoke from the Anglo-Scottish industrial district, or to volcanic dust from distant regions?—*G. H.*

[27] For the sake of brevity the word rime (Rauhreif) alone will be used hereafter, although meaning both Rauhreif and Rauheis.—*G. H.*

[28] On the other hand, the rime [and ice] which forms in the mountain forests is a natural increment of the moisture that reaches the ground. The rime falls off, melts, and increases the amount of water seeping into the soil. It is a "fog drip" (Nebeltraufe) in the solid form.

frost (Reif) and rime (Rauhreif). Certainly both condensations contribute something to the preservation and increase of the snow cover, but their copiousness must not be overestimated. This is shown by the long series of measurements on the summit of the Brocken, of which I submit some of the results.

Rime measurements on the Brocken.

The frequent deposition of rime on the Brocken made it necessary to devise some method of determining possible new formations of this deposit. For this purpose we employed the freely exposed iron mast supporting the wind vane on the platform of the tower. At each observation hour (7ª, 2ᵖ, 9ᵖ) the thickness of the rime that had formed was measured in centimeters and then the deposit was knocked off. It seldom happened that the deposit had fallen off prematurely. In this way was secured the number of days on which rime formed, and also a relative measure of the amount.

The observations from 1897 to 1913 show that on the Brocken summit the average annual number of days with rime is 137.4. The extremes among the individual years were 179 and 108 days. The distribution by months is shown in Table 1.

TABLE 1.—*Statistics of rime on the Brocken and the Schneekoppe.*

Months.	Brocken (1,142 m.), 1898–1913.				Schneekoppe. (1600 m.) 1902–1913.
	Days with rime.		Thickness of rime.		
	Average.	Maximum.	Average.	Maximum.	Average number of days with rime.
	Days.	*Days.*	*Cm.*	*Cm.*	*Days.*
January	23.2	29	423	819	20.1
February	22.8	29	365	715	22.6
March	22.7	27	307	532	21.0
April	14.5	25	153	407	16.0
May	5.9	18	43	134	6.7
June	0.06	1	0.3	5	1.4
July	0	0	0	0	0.2
August	0	0	0	0	0.5
September	0.4	3	2	14	6.1
October	6.1	27	66	459	9.8
November	17.9	28	276	564	19.2
December	23.8	29	386	640	22.2
Year	137.4	179	.....	.....	145.8

It appears from this table that, on the average, about two-thirds of all days during the four months December to March have rime forming. March has a notably large number of days. It is a month that still has a wintery character on the German mountain summits, and, as I have already shown,[29] this month also brings a secondary maximum in snowfall.

I have added to Table 1, for comparison, the average number of days with rime on the summit of the Schneekoppe (Riesengebirge); they are from the 12 years of observations, 1902–1913, during which one and the same observer was on duty. It appears that rime forms on the 1,600-meters-high Schneekoppe somewhat more frequently than on the Brocken (1142 m.). The opposite holds for the true winter months from December to March, but during the remaining months when the mean cloud level is higher, the Schneekoppe has rime more frequently than does the Brocken. During the 17 years mentioned above the Brocken has never had rime form during high summer (July and August), while on the Schneekoppe no month is free from it. It is further worthy of mention that in 1912 even September had 22 days with rime. The amount of the rime deposit on the Schneekoppe seems to be somewhat less than that on the Brocken, which lies nearer the sea.

Observations for 6 to 10 years show that the annual number of days with rime on the Fichtelberg (1213 m.) in the Erzgebirge is 140, on the Inselsberg (914 m.) in the Thuringer Wald is 88, and on the Grossen Winterberg (553 m.) in the Sächsische Schweiz it is 68.

On the highest elevations of the German Mittelgebirge there are but two types of winter weather—viz, in the midst of a cloud or free of cloud. The first condition may endure for weeks and even months, and rime is almost always forming then. Hence the maximum number of successive days on which new rime formed may mount very high. During the 17 years, 1897 to 1913, the maximum has never been less than 10 on the Brocken; in six years it exceeded 30, and in 1908 even amounted to 56, rime forming every day throughout the 8 successive weeks from January 26 to March 21, inclusive.

Although the measurement of the thickness of the rime deposit on the windvane support has but a relative value, it is, nevertheless, worth while to give the average and maximum monthly values (see Table 1, columns 3 and 4), and particularly so since it is probable that they are the only systematic measurements of their kind. Much more interesting than these monthly sums are the individual measurements, for they show what great quantities of rime can deposit in a short time. From one observation to the next, in 7 and 10 hours respectively, the thickness of the newly formed rime often amounted to 20 or 30 cm., in one case even totaling 35 cm.—i. e. 35 mm. per hour. The heaviest deposit in one day, from 7ª to 7ª was 78 cm. on March 26, 1911.

To investigate the effect of rime deposition in increasing the thickness of the snow cover we must select a period when no true precipitation (snow, rain, graupel) falls. The interval, March 19 to 23, 1901, was such a period. During continuous fog, stormy east wind, and temperatures between −1.0° and −10.1°C., rime deposits of the following thicknesses were measured:

Date.	Observation hour.			Total.
	7ª	2ᵖ	9ᵖ	
1901.	*Cm.*	*Cm.*	*Cm.*	*Cm.*
Mar. 19	.....	.....	4	4
20	30	20	25	75
21	21	15	6	42
22	5	5	7	17
23	5	.....	.....	5

In spite of these tremendous rime deposits the depth of the snow cover was increased but 1 centimeter. Even admitting that there is considerable uncertainty involved in the measurement of snow depth, nevertheless these and all other available examples show with sufficient certainty that the deposition of rime on the snow surface is vanishingly small in comparison with its deposition on upright walls, posts, etc.

The terms used to designate rime (Rauhreif) deserve a few remarks. No other hydrometeor has so many different names in German as this rime (Rauhreif).[30] I know the following: Rauhreif (Rauchreif),

[29] *Hellmann, G.* Die Niederschläge in den norddeutschen Stromgebieten. Berlin, 1906. v. 1, p. 218.

[30] One of Chistoni's contributions, mentioned above under footnote 5, shows that although the solid hydrometeors do not often occur in Italy, the Italian language contains a far greater number of names for these phenomena than one would expect. Most of these names, however, seem not to belong to the general written vocabulary; out of the 15 words mentioned there were 8 I could not find in the great Italian dictionary of Petrocchi, Rigutini & Fanfani. Among these words are "galaverna" and "calabrosa," which Chistoni applies, as shown by his context, to rime (Rauhreif) and Rauheis, respectively. Perhaps he will be interested to learn a designation for frost (Reif) which he did not mention. In the work by Rao "I meteori" (Venetia, 1582. 4°) I found the chapter heading "De la brina communemente chiamata gelame" [On frost, commonly called "gelame"].

Rauhfrost, Haarfrost, Nebelreif, Duft, Duftanhang, Anhang, Abhang, Bihang, Anreim, Anraum. In Austria, southern Germany, and Thuringia the most common expression is the ancient one "Duft" (see above, p. 385), but the name "Anhang" is also ancient and is widely used in forest districts (Forstkreisen). (*See* Grimm, "Deutsch. Wörterbuch," v. 1, p. 366, "rîfe und anehanc"). To-day the most usual term in northern Germany and also among meteorologists is "Rauhreif." In the Riesengebirge the phenomenon is called "Anraum," probably derived from "Anreim," which is the more usual form of the word in Austria. This word goes back to the Old Norse "hrim," whence are also derived the English "rime" and the French "frimas."[31]

(*To be continued.*)

ON THE VARIABILITY OF TEMPERATURE.[1]

By ALFRED ANGOT, Director.

[Dated: Bureau Central Météorologique de France.]

The meteorological character of a given day depends, in some degree, upon that of the preceding day and perhaps even upon that of several previous days.[2] The question thus arises whether it is possible to go further and to forecast, e. g., the character of a season from that of the preceding season, or to say if after a series of warm winters the chances of a severe winter are increased. A very large number of similar questions can be raised. Temperatures may be used as a numerical example of the answers to such questions.

The arithmetical mean of the temperatures of the same month for a large number of consecutive years is called the "normal" temperature of that month. The normal temperature for December at Paris is 2.7°C. The temperature of a particular December, for instance, December, 1914, was 6.2°C. The departure of this temperature from the normal December temperature +3.5°C., that is the difference between 6.2° and 2.7°. If all these departures were the result of purely fortuitous causes, the theory of probability would give directly the degree of probability of a departure of a given amount. Thus it will be found that the departure of which the probability is one-half, i. e., the "probable departure," is 1.9°C. In 100 Decembers there would be 50 with a temperature between 0.8° (2.7°−1.9°) and 4.6°C. (2.7°+1.9°). Likewise there would be 18 in which the departure from the normal would exceed twice the probable departure—that is, of which the temperature would be above 6.5° or below −1.1° C. The probability of other departures may likewise be computed.

In a study of the temperatures of France [3] published 16 years ago, observations made during 50 years in 22 different sections of France and neighboring countries were discussed from this point of view. In all these studies without exception the results rigorously conformed to those obtained from the theory of probabilities. The physical causes that determine one month shall be warm or cold are so many and so complex that the net result is the same as that from purely fortuitous causes.

It is possible to go a step further and inquire if these causes have a certain permanence and continue to act in the same sense during a considerable time, two months, a season, or a longer period; in other words, if the character of the beginning of a season justifies a forecast for the entire season, or that of one season a forecast for a later season. If the character of a month (warm or cold) is represented by *A* and the opposite character by *B*, two consecutive months offer the combinations *AA* and *AB*. Likewise for three consecutive months there will be the combinations *AAA*, *AAB*, *ABA*, *ABB*. If there is a relation between the character of one month and that of the following month one of these combinations will appear more frequently than the others.

Observations of temperature made in the vicinity of Paris during the 65 years, 1851 to 1915, have been examined to determine whether such a condition exists. As an example the results for some groups of three consecutive months are given below; the figures indicate the number of occurrences of the different combinations:

	AAA	*AAB*	*ABA*	*ABB*
October-November-December	18	12	19	16
November-December-January	17	17	15	16
December-January-February	18	14	19	14
June-July-August	22	18	12	13

Even for two consecutive months there is no systematic relation. The different combinations have all the same probability as that which appears in the succession of red and black on the roulette wheel.

This is shown even more strongly when successions of longer durations are examined. No relation can be made out between the temperature of one month and that of the following month, still less between the temperature of a season and that of the following season; a warm summer will be succeeded indifferently by a warm winter or by a cold winter.

Forecasts made from the actions of animals or plants are in the same category. There is a belief that when the beech trees lose their leaves earlier than usual an exceptionally early or severe winter will follow. The causes that bring about the fall of leaves from a tree are to be found in the meteorological characteristics of the summer or autumn. It has just been shown that these characteristics have no influence on those of the following season.

Another prejudice not less frequent supposes that the meteorological phenomena tend to be complementary within short periods. From 1909 to 1914 the six consecutive Decembers were all warm. Therefore, if the short-period compensation were effective, the chances that the following December, that of 1915, will be cold would be increased. But this is not the case; past seasons do not control future conditions. After a series of very warm months the chances that the following month will be warm or cold remain equal, which is the same as the chance that red or black will appear at roulette after a run of any kind whatever.

In conclusion, the variability of monthly, seasonal, or annual temperatures in France follows exactly the same law as if the causes were purely fortuitous, and it is not possible to forecast for months, seasons, or years by means of past phenomena.

---

[31] The name "silver thaw," devised by English meteorologists for the phenomenon of rime (Rauhreif), seems to be unable to maintain its footing even in professional circles. Earlier good observers like Luke Howard, Scoresby, and others, always used the word "rime" for this deposit. At present there is great confusion in this matter, for Mossman has applied the name "silver thaw" to the deposit known as "glazed frost" (Engl.), "glaze" (U. S. A.), (Glatteis).

Old French textbooks in meteorology applied the term "frimas" to hoarfrost (Reif) and to rime (Rauhreif). Only within the last 50 years has there been a clear discrimination between "gelée blanche" and "givre" [i. e., between hoarfrost and rime]; while "frimas" has disappeared from the scientific literature.—*Author.*

Translator's note.—The usage in the United States with regard to these terms has been discussed in some detail in the MONTHLY WEATHER REVIEW, May, 1916, 44: 281-286, notably p. 285-6, where the U. S. Weather Bureau officially adopts "Rime" (Rauhreif) and "Glaze" (Glatteis).

The same article also shows to what extent the term "silver thaw" is known and used in the United States and Canada.—C. A., jr.

[1] *Angot, [Charles] A[lfred].* Sur la variabilité des temperatures. Comptes rendus, Acad. agric. de France, Paris, déc. 22, 1915, 1:789-792. *Transl.* by W. G. Reed.

[2] In this connection see: *Newham, E. V.* The persistence of wet and dry weather. Quart. jour., Roy. meteorol. soc., London, July, 1916, 42:153-162. Abstracted on p. 393 of this issue of the REVIEW.

[3] *Angot, A.* Études sur le climat de la France: Temperature, 1ère. Partie—Stations de comparison. Annales, Bur. cent. météorol. de France, 1897, I. Mémoires, Paris, 1899, pp. B93-B170; *ibid.*, 1900, I. Mémoires, Paris, 1902, pp. B33-B118.